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CRUSTAL THICKNESS AND STRUCTURE OF THE NORTHWESTERN PART OF THE WESTERN DESERT, AS DEDUCED FROM INTEGRATED GRAVITY AND DEEP SEISMIC DATA

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استنباط سمك وتركيب القشرة الأرضية للجزء الشمالى الغربى من الصحراء الغربية باستخدام تكامل بيانات التثاقلية والسيزمية العميقة

الخلاصة: تقع منطقة الدراسة فى الجزء الشمالى الغربى من الصحراء الغربية المصرية وتغطى مساحة سطحية حوالى ٥٣ الف كيلو مترا مربعا. وتهدف هذة الدراسة الى القاء بعض الضوء على سمك القشرة الأرضية وكذلك التراكيب العميقة لهذة المنطقة. وقد استخدم لهذة الدراسة خريطة بوجير التثاقلية، وبروفيلين سيزميين عميقين بالاضافة الى بعض المعلومات المستمدة من مجموعة من الآبار المحفورة بالمنطقة. وقد امكن حساب عمق صخور القاعدة بواسطة عدد من البروفيلات باستخدام طريقة التحليل الطيفى، والتى تم استخدامها مع البروفيلات السيزمية فى عمل تسعة بروفيلات (موديلات تثاقلية ثنائية الأبعاد) ، والتى امكن من خلالها رسم ثلاث خرائط توضح شكل وطبوغرافية اسطح صخور القاعدة ، والكونراد والموهو ، وذلك من خلال نتائج هذة الموديلات.

ولقد اوضحت هذة الدراسة ان عمق صخور القاعدة يزداد بصفة عامة من الجنوب (٣- ٤ كم) الى الشمال(اكثر من ٧كم). بينما يزداد عمق كلا من الكونراد والموهو من الشمال الى الجنوب ، حيث يبلغ عمق الكونراد حوالى ١٢ كم فى المنطقة الشمالية البحرية الى حوالى ١٩ كم فى جنوب المنطقة ، وعمق الموهو حوالى ٢٤ كم فى اقصى الجزء الشمالى الشرقى البحرى الى حوالى اكثر من ٣٢ كم فى جنوب المنطقة.

وبصفة عامة امكن تقسيم المنطقة المنطقتين تكتونيتين وهما: المنطقة التكتونية الجنوبية ، جنوب الشريط الساحلى بحوالى ٢٠ كم وهى تمثل ثلثى المنطقة تقريبا ، وهى تمثل النوع القارى المتوازن ، ويتراوح سمكها مابين ٢٨ كم الى ٣٢ كم تقريبا. المنطقة التكتونية الشمالية ، والتى تمثل الثلث الشمالى بما فيها النطاق الساحلى ، وهى تمثل قشرة ارضية انتقالية غير متوازنة ، ويتراوح سمكها مابين ١٢ الى ١٩ كم .

كذلك اظهر شكل وتكتونية صخور القاعدة والكونراد والموهو ارتباط المنطقة الوثيق بتكتونية البحر المتوسط واللوح الأوربى الأسيوى .

ABSTRACT : *The present study deals with the basement, Conrad and Moho discontinuity depths through nine 2-D density crustal modeling covering almost the Bouguer gravity map of the northwestern part of the Western Desert. Besides, the work is supported by the spectral analysis technique for depth estimation in addition to the fault trend analysis.*

The depths obtained from the spectral analysis and the basement depth from the drilled well(Umbarka-1), in addition to subsurface geological information from about twenty drilled wells are aided in construction of the crustal modeling profiles. Consequently, three depth maps for the basement, Conrad and Moho discontinuities are constructed. These maps indicate that the study area is subdivided into two distinct tectonic blocks of different crustal type, evolution and isostatic characters; these are the southern and the northern blocks. The basement depths, generally, increase from the south to the north, it reaches about 3-4 Km in the southern parts to more than 7 Km in the northern (offshore) parts. In contrast, the Conrad and Moho discontinuity depths increase from the north to the south, where the Conrad depths are about 12 Km in the northern (offshore) areas to more than 19 Km in the southern (continental) parts. Mohole discontinuity depths reach about 24 Km in the marine areas to more than 32 Km in the southern continental areas. The areas between the southern continental block and the offshore oceanic one (along the coastal plain) are transional zones.

Results of trend analysis indicate that the area is greatly affected by six fault trends; they are E-W, NE-SW, WNW, NW-SE, N-S and NNE trends. The first three trends are the main controlling trends of the basement rocks and rejuvenated through the geological history of the area with the other three trends. The area attains also a number of sedimentary basins separated by high areas and trending mainly E-W, NW-SE and NE-SW.

INTRODUCTION

The northern part of the Western Desert has a great importance in various development and agricultural projects. The study area is located in the northwestern part of the Western Desert between Latitudes 30° 00̀ – 32° 00̀ N. and Longitudes 25° 00̀ – 27° 30̀ E. (Fig. 1). It covers a surface area of about 53,000 sq. km within the unstable shelf of Egypt. In addition, this area contains a number of oil and gas fields such as kanayis, Salam, kenz, Hayat, yasser, safir, meleiha, obaiyed, BED and others.

The main objectives of this study are studying of the regional behavior of the basement, Conrad and Moho discontinuities, in addition to detection of the subsurface structural configuration of the northwestern part of the western desert.

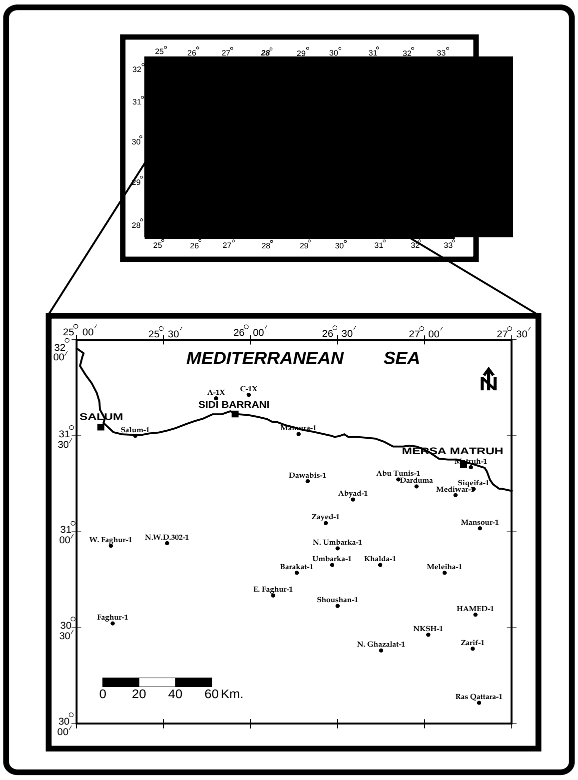

Fig. (1): Location map of the study area showing the location of some drilled wells.

The geophysical and geological data on which the present study based on are; i) The Bouguer gravity anomaly map (fig. 4) with scale of 1:500,000, compiled by the Egyptian General Petroleum Corporation (EGPC. 1982), ii) Two Deep Sounding Seismic (DSS) profiles, one along Sidi Barrani – sidi Abdel Rahman and the other running between Sidi Barrani and Siwa (after Makris et al., 1979), and iii) Some previous geological and geophysical studies, in addition to information from some drilled wells in the area.

These data are analyzed and interpreted qualitatively and quantitatively through the following steps; (i) Analysis of the gravity map, (ii) Analysis of tectonic trends, (iii) Depth estimation by spectral analysis technique, and (iv) Construction of the basement, Conrad and Moho maps based on nine two-dimensional density models, covering almost the study area.

The obtained results were correlated with the available geological, geophysical and subsurface data of the study area.

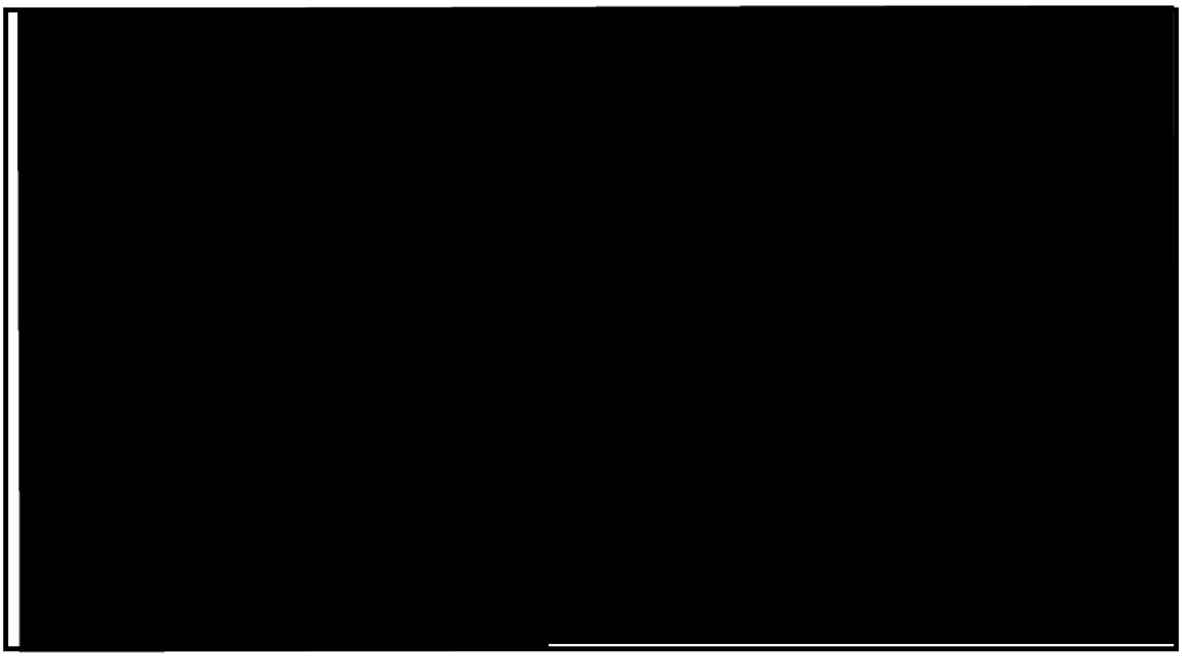

Fig. (2) Map showing distribution of the Marmarica Formation (after Said, 1962)

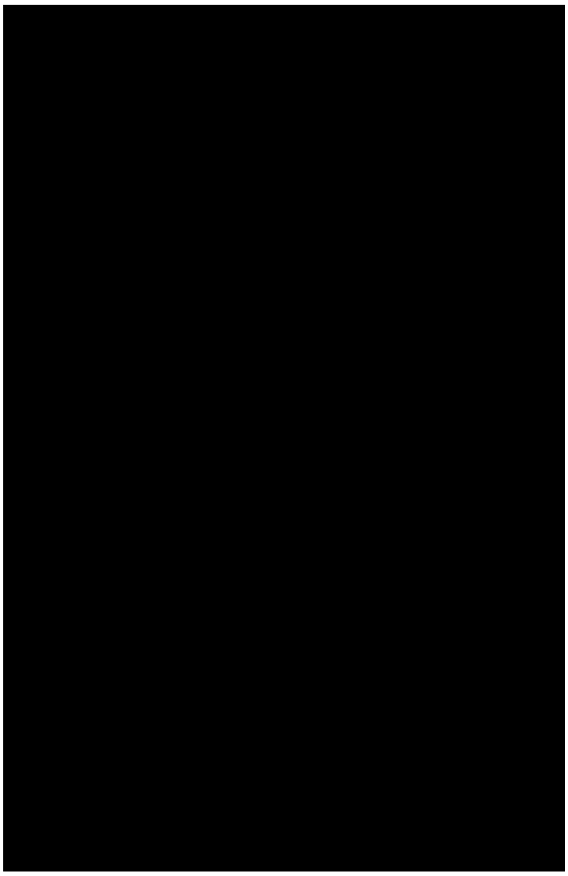

Fig. (3) Generalized litho-stratigraphic column of northern Western Desert (Schlumberger, 1984 and 1995).

GEOLOGICAL SETTING

The northern part of the Western Desert is generally a rocky platform of low altitude and sand plains with no true mountains. According to El Shazly et al. (1980), the surface geology of the north Western Desert is simple and dominated by sedimentary succession ranging in age from Cretaceous to Quaternary. The study area lies generally to the north of the Qattara Depression (Fig. 2), this area is known as El Diffa plateau which slopes gently to the Mediterranean Sea and made up of marmarica limestone of Middle Miocene age. The Mediterranean coastal plain is varies in width from less than one km at the Egyptian – Libyan frontiers to about 50 km along the area between Sidi Barrani and Mersa Matruh. However, this zone is occupies by alluvial deposits, gravel plains and sand dune accumulations (Shata, 1963).

The subsurface stratigraphic succession of the northern part of the Western Desert is, generally, studied and discussed by great number of authors, from those Said (1962 and 1990), Norton 1967, El Gezeery et al. (1972), Abdin (1974), Salem (1976), Abu El Naga (1984), Barakat and Darwish (1987), Taha and Abdel Halim (1992) and others. Fig. (3) shows the generalized litho- stratigraphic column of the northern Western Desert (after Schlumberger, 1984 and 1995). This sedimentary section ranging in age from Cambro-Ordovician to Recent and rests unconformably over the basement rocks which is of crystalline nature (Meshref, 1980). Barakat (1982) subdivided the whole sedimentary section of the north Western Desert into the lower clastic division (Cambrian to Early Mesozoic), the middle calcareous division (Cenomanian to top Eocene), and the upper clastic division (Oligocene to Recent).

GEOTECTONICS AND STRUCTURES

The northern half of the Western Desert forms the major part of the unstable shelf characterized by simple surface geological structures. It represented by northerly dipping Tertiary strata of wide regional extent and uniform lithology. Moreover, the area forms a distinct structural unit which is characterized by a number of gentle, nearly NE-SW and E-W trending elliptical anticlines and intervening synclines. These folds are breached by erosion and cutted by faults, which have E-W, NE-SW and NW-NW trends (Youssef, 1968 and Sultan and Abdel Halim, 1988).

Abdin (1974) stated that, northern Western Desert has been subjected to many diastrophic phases throughout its geologic history. During the Paleozoic times at least two phases, the Caledonian (Early Paleozoic) and Hercynian (late Paleozoic).These orogenies produced a generally N-S trending systems of folds and faults. Early Alpine orogenic phase continued throughout late Jurassic, Cretaceous and Early Tertiary. Atlas orogeny caused deformation of the uplifts and elevated blocks. The later (Laramide) took place in the Late Cretaceous - Early Tertiary and produced the famous Syrian Arc system of folds

Riad (1978) pointed that there are two stress fields probably acting during the different geologic episodes in the northern part of Egypt. A meridinal N-S stress field acting since Early Carboniferous times is believed to be related to the drifting of Africa continent and the interaction between the Africa and European plates. The second field is the modified equatorial one which has acted since Oligocene times and is due to the Red Sea rifting.

Meshref et al., (1980) and Abu El-Ata (1981) reported that, during Jurassic, the continent of Gondwana (to which Africa belong) rotate in a counter clockwise, motion, closing their Ocean. This generated a left - lateral couple force in NE Africa, resulting in the formation of structures with WNW-ESE trend.

Meshref (1982) concluded that northern Egypt is affected by three major tectonic events. The oldest one most probably of Paleozoic to Triassic age which generated the WNW trending structures. The second event is mainly of Cretaceous age, trending NE-SW. The third tectonic event of Late Eocene to Early Oligocene times that generating the E-W, NW-SE and the NNE-SSW trending structures. This may be due to the Collision of Africa with Asia, which generated the north compressive forces.

DATA PROCESSING AND RESULTS

1- Analysis of gravity map:

The Bouguer a anomaly map of the study area (Fig. 4) is characterized by general and rapid increase in the gravity field from the south to north, where the gravity value is less than – 4 mGal in the southwestern parts (near Siwa Oasis) and less than + 10 mGal in the southeastern parts to more than + 70 mGal above the Mediterranean shore line (between Sidi Barrani and Mersa Matruh). This increment of the gravity values towards the north may be due to (i) the presence of more dense subsurface rocks to the north, or (ii) thinning of the earth's crust towards the coastal zones, or (iii) presence of subduction zone or oceanic crust in the Mediterranean Sea.

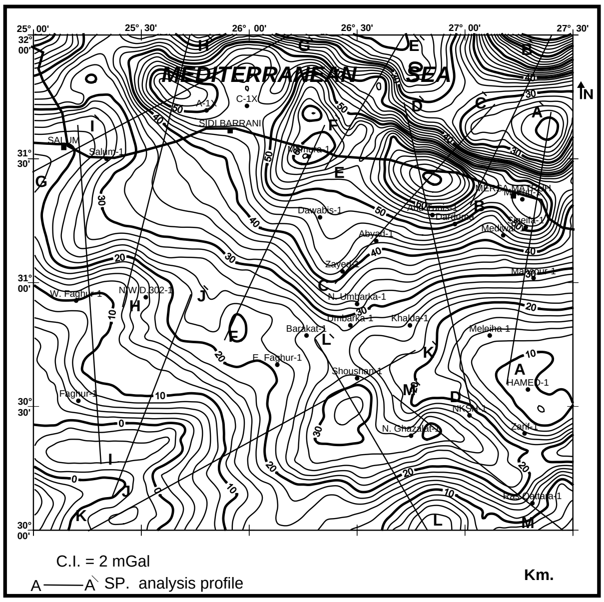

Fig. (4): Bouguer gravity map showing the locations of spectral analysis profiles, (after EGPC, 1982).

In addition, the regional anomaly features are complicated by several local anomalies of different intensities, shapes, extensions and amplitudes with irregular contour pattern. Such features could be due to the fact that the gravity field contains combination effects of all gravitational sources present at and below the earth's surface. These are probably due to faults that separate different blocks of the basement rocks.

The low and negative gravity anomalies in the southern parts of the area may indicate the presence of large sedimentary basins. Generally, the gravity map reveals tectonic trends in the E-W, NE-SW, NW-SE and N-S directions. These trends believed to be the main tectonic trends affecting and controlling the basement rocks as well as the overlying sedimentary succession.

2- Analysis of tectonic trends:

Since the interpretation of the observed gravity anomalies reflect fairly well the subsurface geologic conditions in the investigated area. Then it can be considered that such anomalies may be related, as a first approximation, to certain geologic elements in the earth's crust. So, the purpose of this trend analysis is to define statistically the major tectonic trends, which affected the sedimentary section as well as the basement rocks of this area.

Trends in the form of fault lines at the zones of steep gradients are traced out, statistically analyzed and represented as a fault pattern of the area (Fig. 5) and block diagrams (Fig. 6), in percentages of the total lengths and numbers. The different peaks on these diagrams are considered to represent the major trends of different fracture systems, or tectonic pattern trends, in the studied area. Further, the relative magnitude of the peaks could be regarded as a reflection of the magnitude and frequency of deformation that resulted from various forces that were active in different geologic ages.

The fault pattern (Fig. 5) with the direction of the fault throws reflects some basinal or down faulted blocks which may represent some basins in the area such as Faghur and Shushan basins to the west in addition to Matruh and Meileha basins to the east. While, along the shore line (between Sidi Barrani and Matruh) there are three elevated or uplifted blocks. They may represent the Khramana platform to the west and Matruh platform to the east.

The block diagrams (Fig. 6) indicates that the study area, as well as, the north Western Desert is affected generally by six tectonic trends. According to their cumulative lengths, taking the directions: Mediterranean (E-W), Syrian Arc (N45°-65°E), Najd (N65°W), Suez (N35°-45°W), East Africa (N-S) and Aqaba (15°-25°E), arranged in a decreasing order of predominance. The first four trends are generally affected the larger structures in the north Western Desert , while the last two are of minor nature and controlled by the first group. Generally, the detected trends are more agreeable with those previously interpreted by various authors, except for the order of predominance.

In addition, these tectonic trends explain well the tectonic framework and tectonic history of the study area and the north Western Desert.

*** Mediterranean (E-W) trend**: It is the most important trend in the investigated area, seems to affect both deep and shallow structures. This trend probably controls the basement blocks and its directional control related to a Pre-Cambrian structural direction. It has been rejuvenated during several orogenies, especially those related to the Late-Tertiary compressional forces (Youssef, 1968 and Halsey and Gardner, 1975). Bayoumi (1983) added that the E-W trend is the common direction of faults in the exposed Pre-Cambrian of Egypt.

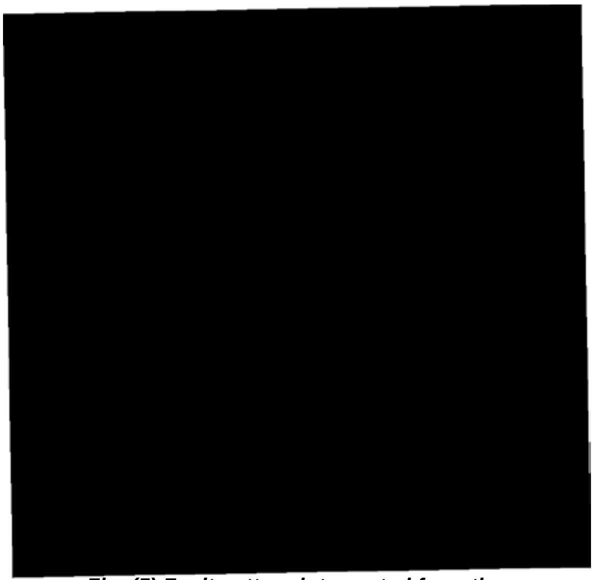

Fig. (5) Fault pattern interpreted from the Bouguer anomaly map.

Abu El Ata (1988) concluded that the ENE-WSW and WNW-ESE trends which formed the main E-W trend was due to plate divergence between Africa and Asia and Sea floor spreading within the Red Sea, that initiated the Mediterranean Sea system of faults and folds during the Late Tertiary. This is synthesized from the main stress trending to the south and its anti-stress orienting to the north (Fig. 7a and b).

* **Syrian Arc (N45°-65°E) trend**: It is the second trend in importance in the study area. It is the principle controlling direction of the major folding running ENE across Egypt, from Libya to the Dead Sea rift (Said, 1962). According to Abu El Ata (1988), this trend was due to continental separation between Africa and Asia and plate convergence from Europe to Asia that produced the Syrian Arc system of folds and faults during the Middle Mesozoic- Late Mesozoic. This resulted from a main stress trending to the southeast and its anti-stress orienting to the southwest (Fig. 7a and b). The Mediterranean (E-W) and Qattara (NE-SW) trends are the most dominant and oldest tectonics in the area, as well as north Egypt.

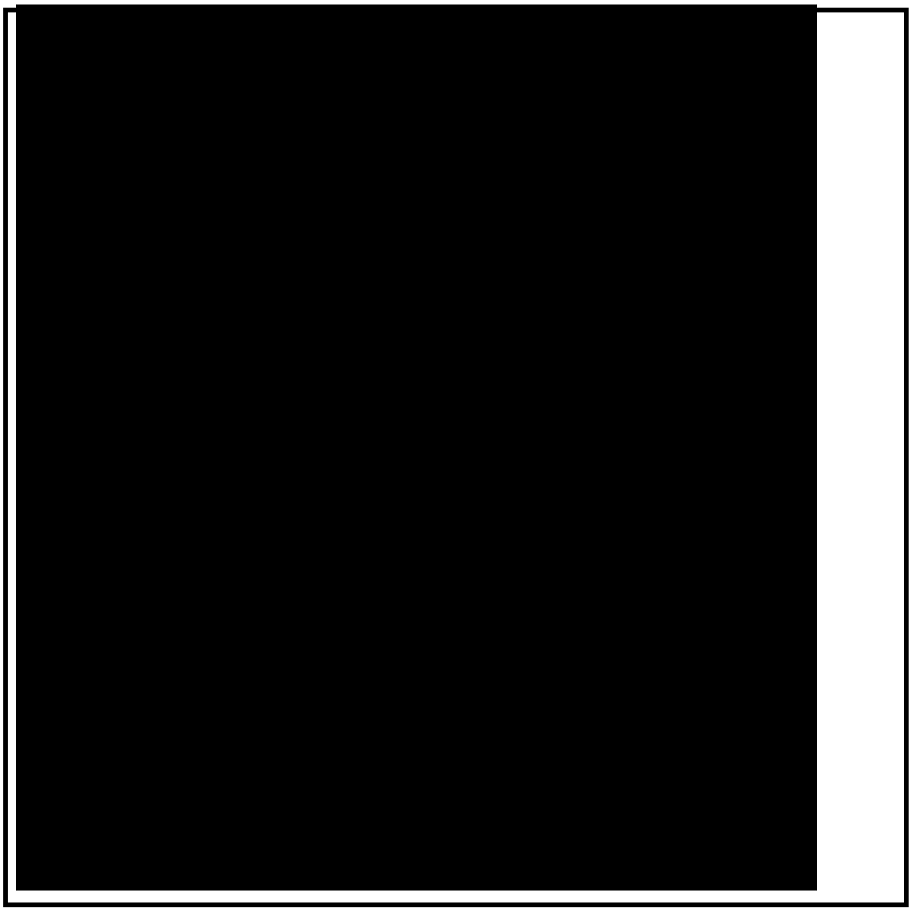

Fig. (6) Block diagrams showing the length and the number percents (L% and N%) versus azimuth of the fault systems interpreted from the Bouguer gravity map.

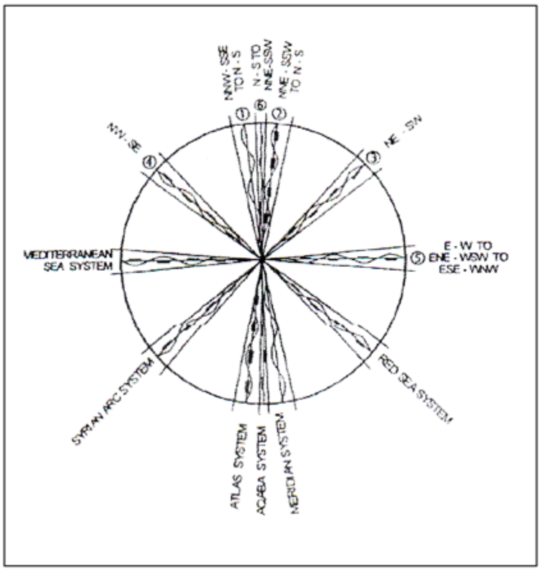

Fig. (7-a) Systems of regional structural deformations in Egypt (After Abu El- Ata, 1988).

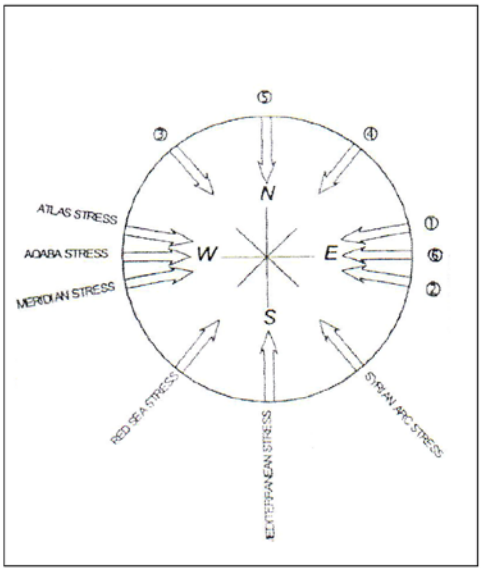

Fig. (7-b) Stresses f regional tectonic deformations in Egypt (After Abu El- Ata, 1988).

* **Najd (N 65° W) trend**: The third in importance is the WNW trend. It is one of the strongest and widely spread trends in Egypt and the Arabian shield. Youssef (1968) considered that this trend in addition to the ENE (Syrian Arc) trend is the two basic tectonic trends affecting northeast Africa. Halsey and Gardner (1975) mentioned that this direction was probably developed as a shear and drag fold trend resulting from left-lateral shear in the Tethyan area, during Jurassic- Cretaceous times.

* **Suez (N45°W) and Aqaba (N15°-25°E) trends**: These tow tectonic trends are considered as two ideal and complimentary sets of shear fractures, which may be resulted from a northern horizontal compressive force oriented in N 10° W direction (Youssef, 1968). They may be of Pre-Cambrian age but actively rejuvenated during the Late Tertiary Alpine orogeny (Riad, 1977). According to Bayoumi and Boctor (1980), most of faults running parallel to the Gulf of Suez are shown up with a transcurrent movement of left-lateral component, whereas most of the major fault zones which trend rather than N-S are shown up with a right-lateral transcurrent movement.

Meshref (1982) concluded that, the Suez and Aqaba trends show a relative strength in north Egypt with lesser magnitude in the southern portion of Egypt or the Arabian shield. The Suez trend shows always a stronger magnitude than the Aqaba trend, which seems to be of local nature. Abu El Ata (1988) concluded that, the Suez (NW-SE) trend is resulted from plate collision and oceanic rifting which is comparable to the upper part of the early Alpine orogeny and resulted in the Red Sea system of block faulting, thrusting and folding during Early Tertiary (Fig. 7a and b).

* **East African (N-S) trend**: It is an important direction throughout Egypt and considered as tensional resulting dynamically from Late- Tertiary and possibly a Hercynian compressional stress field. They also correspond to a meridianal stress direction. This trend has been recorded in both shallow and deep structures. Abu El- Ata (1988)pointed that this trend is due to continental up arching and crustal rifting that comparable to the Hercynian orogeny and resulted in the Atlas system of folding and fracturing (NNW-SSE trend) during Late Paleozoic-Early Mesozoic (Fig 7a and b).

3- Depth determination (spectral analysis):

Calculations of the depth to the basement rocks and/ or intrusions are very important to outline, quantitatively, the thickness variation of the sedimentary cover and to delineate the structural relief of the buried basement rocks and its effect on the overlying deposits. Therefore, spectral analysis technique is applied as one of the useful tools to interpret the basement depth along a number of profiles. This technique was treated by many authors such as Spector (1968) Treitel et al. (1971), Bath (1974), Cassano and Rocca (1975), Bhattacharya, (1978), spector and Parker (1979) and others.

Generally, all spectra of the Bouguer anomalies include two parts, one in the low-frequency end, which in most cases is easier to approximate with a straight line and denoting deeper discontinuities (Moho and/ or Conrad). The second is in the high-frequency end, with an undulating character, denoting shallower sources (basement and/ or intrusions). On these bases, the depths to the earth's discontinuities (Moho, Conrad, basement and/ or intrusions) are calculated from the graphical presentation of log amplitude spectra using technique of Sadek (1987), through thirteen profiles applied to the

Bouguer gravity map covering almost all the anomalies on the map. The location of these profiles are illustrated on the Bouguer gravity map Fig.(4), and the obtained depths (deep and shallow) are shown in table (1). Fig. (8) displays four examples for the spectral analysis calculations along these profiles.

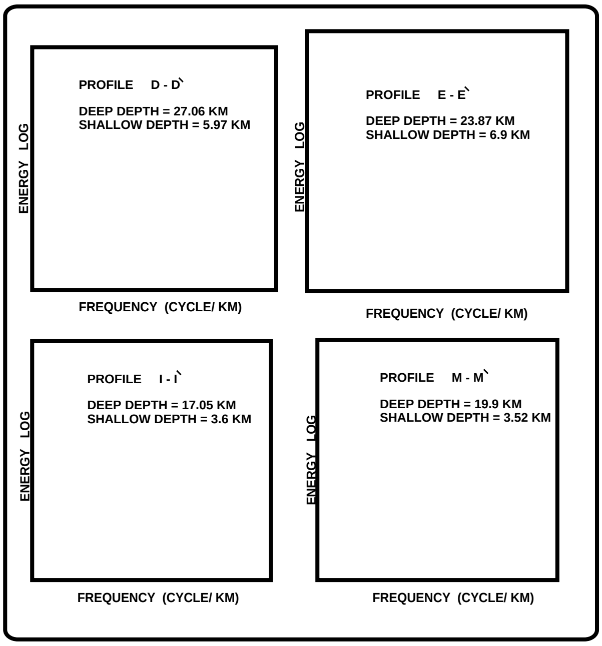

Fig. (8): Estimated depths using spectral analysis technque, along pfiles D- D`, E- E`, I- I`and M- M`.

From the obtained results (table 1), it can be illustrates that the average estimated depth of the basement rocks and/ or intrusions are in the limits of 2.5 - 4 km. in the southern parts, 4 - 5.5 km in the central parts and 5.5 – 7 Km in the northern offshore parts.

This indicates that the basement depths are, generally, increase from the south to north. Otherwise, the deeper depth to the crustal discontinuities (Conrad and Moho) is also calculated along these profiles.

Table (1): Depths of Moho, Conrad and basementas determined from spectral analysis profiles.

Profile Name	DEPTH (Km.)		
	MOHO	CONRAD	BASEMENT
A - A`	27.06	-	5.22
B - B`	25.46	-	6.43
C - C`	-	16.59	5.49
D - D`	27.06	-	5.97
E - E`	23.87	-	6.90
F - F`	28.86	-	5.71
G - G`	28.48	-	5.68
H - H`	-	17.90	5.67
I – I`	-	17.05	3.60
J - J`	-	18.81	4.58
K - K`	-	18.72	3.25
L - L`	-	19.81	2.68
M – M`	-	19.90	3.52

Some profiles reveal the Moho depths, while the others reflect the Conrad depths. The depths to the Conrad and Moho discontinuities are increase generally, from the north to the south, as shown from some estimated profiles (table 1).

4- Two- Dimensional Modeling:

To provide some additional information about the deep structure of the crust and upper mantle as well as to throw more lights on the geometry and evolution of the study area, two-dimensional gravity modeling on the base of deep seismic sounding is carried out.

It is well known that, both gravity and deep seismic data are widely accepted for solving tectonic problems and proved to be closely connected with the crustal thickness (woollard, 1959). However, neither gravity data alone nor deep seismic can yield a unique solution for density distribution, but combination of them may give better results. Consequently, the gravity modeling based on seismic data, can help in delineating crustal structures as well as Conrad and Moho boundaries. Moreover, it may provide additional structural information and allow possible interpolation between certain seismic boundaries.

Modeling is based on the assumption that the velocity boundaries outlined from seismic refraction data could be resemble density boundaries (Theilen and Meissner, 1979). According to Meissner (1986), the boundaries for refraction profiles are; (i) The base of the sediments, often marked by velocities (Vp) between 3.5 and 4.5 Km/s, (ii) The intra- crustal Conrad boundary, defined as a rather sudden jump from velocities 6 to 6.5 Km/s to Vp > 5.5 Km/s, (iii) The- crustal mantle Moho boundary where the velocities (Vp) range between 7.5 to 8 Km/s.

The p-wave velocities are converted into density values with the use of woollard's conversion of crustal velocities to densities (Fig.18) (Woollard, 1959 and Barton, 1986) empirical function. He stated that plots of seismic velocity and density of rock samples show that the range of densities is possible for rock of each seismic velocity and vice versa, although a single linear relationship is often assumed in crustal gravity calculation. In the present study, the modeling is based on the two-dimensional gravity field algorithm developed by Talwani et al (1959), using the modified program after Rudman and Blackely (1983). Crustal models are preformed along nine profiles (Fig. 9) trending in the NW-SE and NE-SW directions. These profiles are selected to cross nearly all the anomalies recorded on the gravity map.

The starting crustal model depends essentially on the available deep seismic sounding profiles (Figs.11 and 12), previously made along Sidi Barrani- Siwa and Sidi Barrani- Sidi Abdel Rahman, after Makris et al. (1979). Some Velocity- depth (V-Z) functions, from the refraction profiles are picked up. Moreover, deep and shallow depths of Moho, Conrad and basement, calculated from spectral analysis in addition to the surface and subsurface geological information (from about 20 wells drilled in the area) are also used during the modeling processes. These data are used to construct the starting models along the first group of NW-SE profiles (M_1 to M_5), which are crossed by the second group of NE-SW profiles (M_6 to M_9) as shown in Fig. (9). At the intersection points, the V-Z functions are correlated to each other to construct the starting model for each of the crossing (NE and NW) profiles.

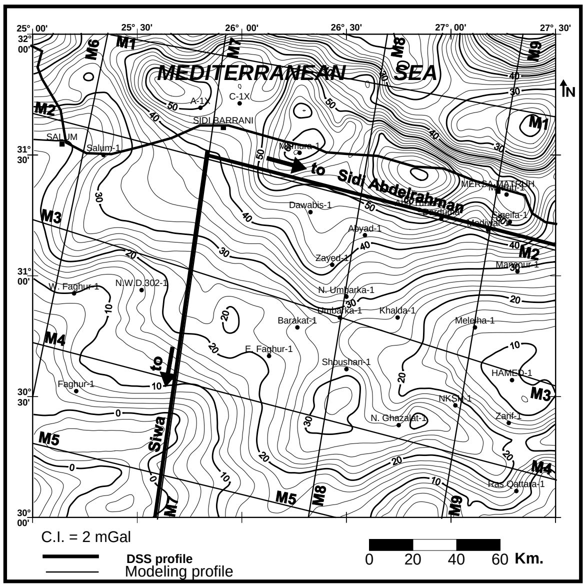

Fig. (9): Bouguer anomaly map of the study area showing the the location of DSS and modeling profiles.

In addition, Umbarka-1 well, which is the only well reaches the basement surface at depth 3.7 Km, is also used in starting model for models M_3 and M_8. Depths estimated by spectral analysis technique are also taken into consideration. In the final model, the surface geology along each profile and the variation of both Conrad and Moho boundaries are taken also into consideration. Four examples of 2-D gravity modeling along the first and second groups of profiles are presented through Figs. (13 to 16).

The obtained results from these nine profiles are picked up, for each discontinuity, and contoured to give three maps for regional depth and relief of the basement, Conrad and Moho discontinuities Figs. (17 to 19), to illustrate the crustal thickness and structures of the study area.

Fig. (17) shows the regional trend of the basement depth as deduced from the gravity modeling. Generally, high depth values (about 7 Km) are encountered in the northern portions, along the Mediterranean Sea coast. This depth increases northward (inside the sea) till reaches more than 9 Km. Toward the south; this depth decreases to be found less than 3.5 Km. This map shows no details about the basement surface changes, since it gives a preliminary idea about the regional trend of the basement depth in this area.

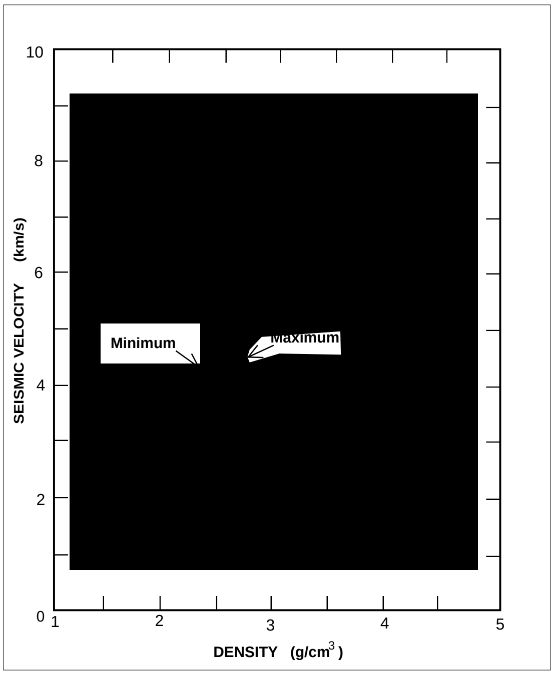

Fig. (10) Seismic velocity-density relationship, after Woollard (1959) and Barton (1983).

Fig. (11) Crustal model below Sidi Barani – Sidi Abdel Rhman (Makris et al., 1979)

Fig. (12) Crustal model below Siwa-Sidi Barani (Makris et al., 1979)

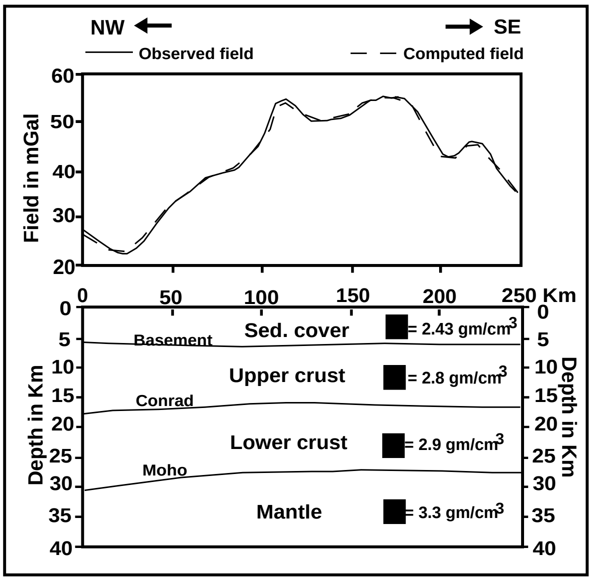

Fig. (13) Gravity modeling alomg profile M2 - M2

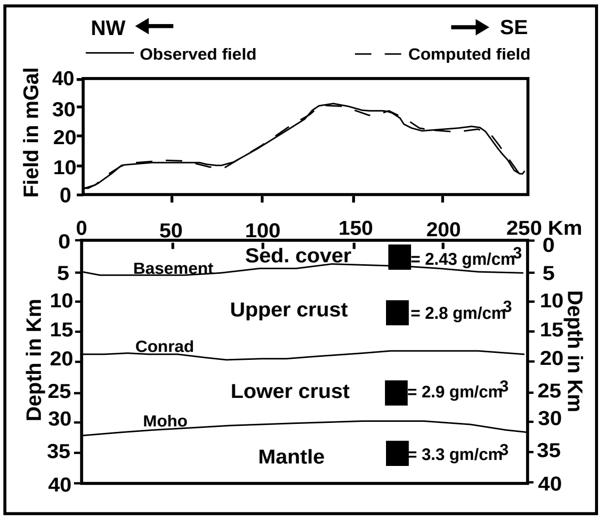

Fig. (14) Gravity modeling alomg profile M4 - M4.

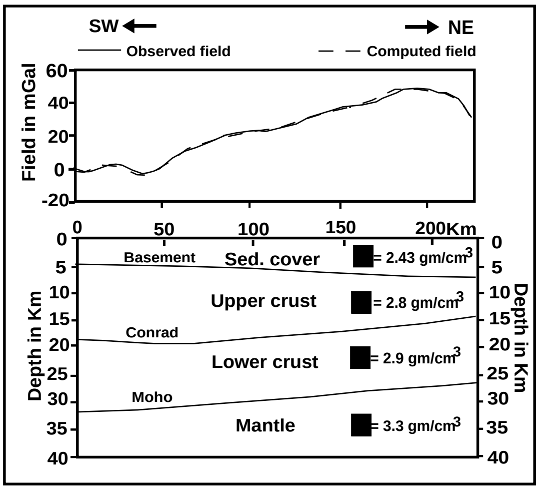

Fig. (15) Gravity modeling alomg profile M7 - M7.

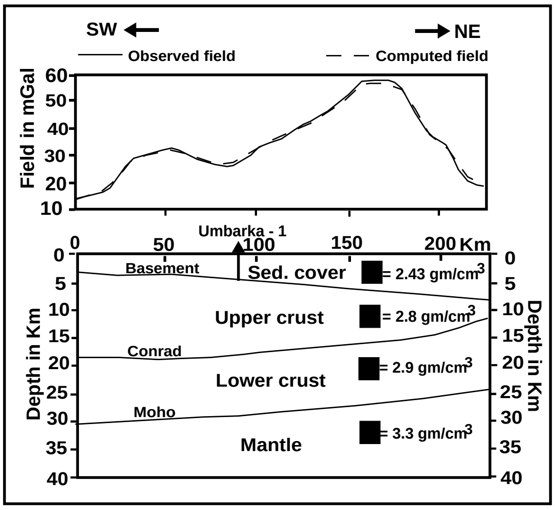

Fig. (16) Gravity modeling alomg profile M8 - M8.

The Conrad depth map (Fig. 18) shows that the depth of the intra-crustal (Conrad) boundary increases, generally, from the north to south. It attains a maximum depth in the south and southwestern parts (more than 19.5 Km), while this depth decreases northward until reaches less than 13 Km in the northeastern offshore parts, with steep gradients.

Fig. (19) shows also a general increase of the depth of the Crustal- Mantle (Moho) boundary from the north to south. In the southern parts, depths reach their maximum values, more than 31 Km, in the southeastern parts (near the Qattara Depression) and more than 32 Km in the southwestern parts (near Siwa Oasis). In the middle parts, the depths vary between 27 and 29 Km. This depth is gradually decreases seaward until reaching its minimum values (less than 24 Km) in the northeastern offshore parts of the area.

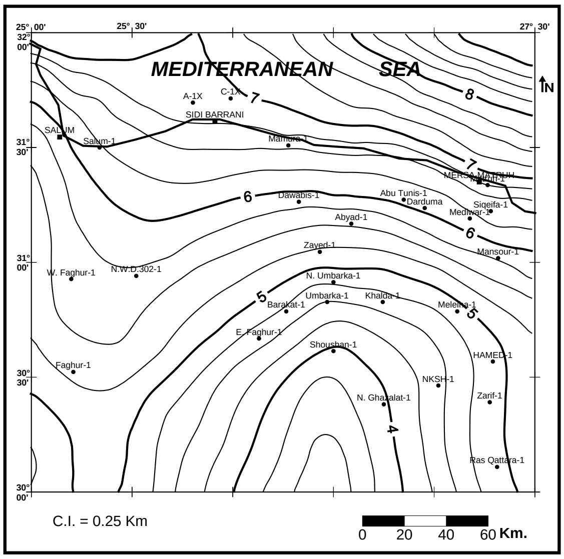

Fig. (17): Regional basement depth map of the study area as intepreted from the modeled profiles.

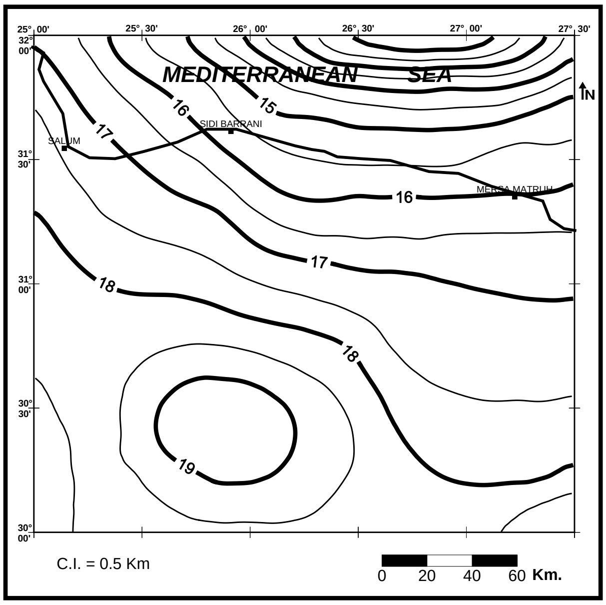

Fig. (18) Conrad depth map of the study area as intepreted from the modeled profiles.

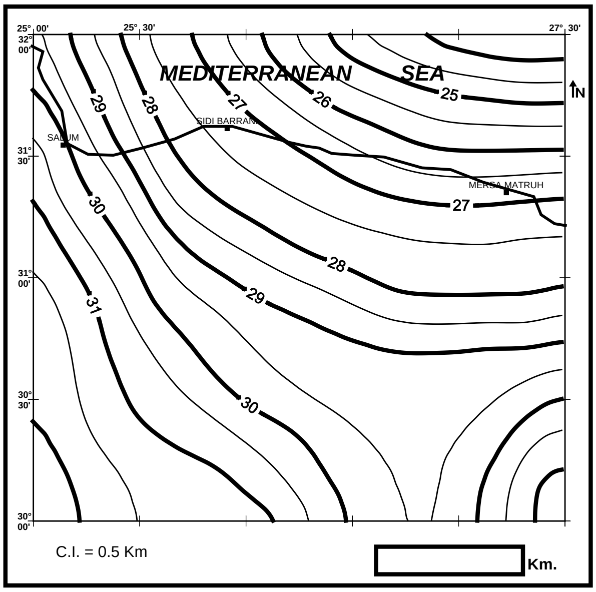

Fig. (19) Moho depth map of the study area as intepreted from the modeled profiles.

Based on the results obtained from the crustal modeling, the following can be stated:

1- The shape and relief of the Conrad and Moho boundaries below the study area reflect, to great extent, the shape and values of the Bouguer anomalies. This indicates good correlation between the topography of the crustal discontinuities and the regional gravity field.

2- The crust thickens landwards and thins seawards.

3- The study area can be divided into two distinct tectonic blocks, they are:

a- The southern tectonic block: This occupies about tow- third of the study area. It is isostatically compensated with a crustal thickness varying between 28 to 32 Km. All the earthquakes observed in this zone are historical (Maamoun et al., 1980). The velocity structure is that of typical continental crust with a normal upper mantle velocity.

b- The northern tectonic block: It represented by the Mediterranean coastal sub area, and characterized by a decrease of crustal thickness towards the Mediterranean Sea. This block is related to the Eurasian plate and is associated with a very old passive margin and may be affected by the Paleozoic sedimentation.

The sediments accumulated due to the stretching and subsidence of this passive margin is of 6 to 7 Km thick at the Mediterranean coast of Egypt. This may be due to that the Mediterranean coast has been affected by a lot of shearing forces. According to Maamoun et al. (1980), the Egyptian- Mediterranean coastal area represents a unique seismic zone. The earthquakes in this zone have magnitudes between 5- 6, this zone occurs in relation to the continental shelf (the canyon off Alexandria) and continental slope. The focal mechanism off Alexandria shows a dextral- strike- slip movement (McKenzie, 1970).

CONCLUSIONS

From the present study, the following conclusions can be summarized:

1- The study area is affected mainly by six tectonic trends, they are; the Mediterranean (E- W), Syrian Arc (N 45°-65°E), Najd (N65°W), Suez (N35°-45° W), East African (N-S) and Aqaba (N15°- 25°E) trends. These trends indicate that north Western Desert is greatly affected through its geologic time, from the Pre- Cambrian to the Lat-Tertiary, by a number of tectonic movement affecting north Africa, especially the northeast.

2- Spectral analysis and 2-D Modeling techniques indicate that the basement depths increase generally from south to north, while the Conrad and Moho discontinuities increase from the north to south

3- The northern part of the Western Desert can be divided into two distinct blocks of different crustal type, tectonic evolution and isostatic character, these are:

a) The southern tectonic block: This occupies the southern two- third of the study area and represented by isostatically compensated continental crust with crustal thickness varying between 28 and 32 Km.

b) The northern tectonic block: It is represented by the Mediterranean coastal sub area and characterized by a decrease of crustal thickness towards the sea (bout 27 Km). This block is most probably, related to the Eurasian plate and associated with a very old passive margin and may be affected by the Paleozoic sedimentation, where the sedimentary thickness reaches about 7 Km.

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